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WATER SCIENCE, POLICY, AND MANAGEMENT

A GLOBAL CHALLENGE



WILEY Blackwell

Water Science, Policy, and Management

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A Global Challenge

Edited by

*Simon J. Dadson, Dustin E. Garrick, Edmund C. Penning-Rowsell,
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Foreword

I still recall fragments of some of those conversations that subsequently helped to shape my view of the world.

Over 30 years ago, visiting Egypt as Britain's Development Minister, a young man who worked for an NGO said to me, 'I don't understand why everyone is so obsessed with the politics of oil. In time, they will have far more reason to be worried about the politics of water.'

He was right. And it was, of course, a point made sometime in the millennium before the birth of Christ by Job, who had plenty of other things to worry about. 'But the mountain falls and crumbles away, and the rock is removed from its place; the water washes away the stones; the torrents wash away the soil of the earth; so you destroy the hopes of mortals.'

Hope is not the only casualty. Job could have added that peace and stability are victims too.

A former secretary-general of the UN opined that the next war in north-east Africa would be caused by disputes over access to the waters of the Nile. Equally bleak predictions could be made about the Jordan River, and to the east about the Tigris and Euphrates. In central Asia and the Punjab (which means 'land of five rivers') there are similar concerns.

Populations increase exponentially even in places where there is severe water stress, and larger populations demand more water to help produce their food. Food shortages and price rises have always been sure-fire causes of domestic unrest.

Climate change increases stress in areas that are already suffering economically and politically. Migration from arid to more favoured environments is an inevitable result. We know that economic migration – and the movement of people because of political turbulence – have roiled the prosperous northern democracies to which poor, hungry and thirsty people seek to move. This will get worse unless we act.

Water is such a precious resource which, like others, is not fairly distributed around the globe. The rich get more and invariably pay less for it (unless, I suppose, it is bottled!). So the study of how to do the best job of finding, storing, managing and cleaning water, and paying for it too, deserves more political attention and more research funding. This is true in all parts of the world, not least fast-growing Asia and Africa, where so many cities face imminent water shortages and where so much of the existing supply is polluted.

I hope that the essays in this book will help to stimulate more intense and informed debate about a subject where more international cooperation will be necessary for

success. We cannot, to paraphrase Benjamin Franklin, wait to learn these lessons until the wells and aquifers are dry.

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Water Science, Policy, and Management

Introduction

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1.1 Introduction

Understanding the risks and opportunities presented by the changing water cycle, and the intensifying demands and competition for freshwater, is one of the most pressing challenges facing scientists, water managers and policy-makers. In the context of rapid climate, land cover and other environmental changes, the requirement to protect communities against water-related natural hazards, the stewardship of water resources to provide reliable water quantity and quality, and the provision of clean, safely-managed drinking water and improved sanitation to a population predicted to exceed 9 billion, constitute a defining challenge for the twenty-first century. This challenge has inspired the University of Oxford to offer a graduate programme in Water Science Policy and Management since 2004, which to date has seen over 350 students from 57 countries graduate, of which more than half are women. This book is formed from contributions by more than a dozen academics and practitioners who have taught the course, in each case writing in co-authorship with more than two dozen alumni.

This introductory chapter outlines key drivers of change in the water environment and explains how these drivers may evolve into the future, creating new issues and risks requiring interventions. We then outline what we consider to be key challenges facing those responsible for water and its governance and management, globally, in the context of scientific understandings, policy priorities, and management opportunities. We make reference here to the chapters that follow on particular aspects of water science, policy and management, thereby contextualizing those chapters and enabling the reader to see them in a broader context. The final chapter of this book (Chapter 20) gives our vision for the future role of interdisciplinary water education and research in creating greater understanding of the complexities involved and the opportunities for progress.

1.2 Drivers of Change: Environment, Politics, Economics

The water sector is strongly impacted by the recent, rapid, and widespread effect of economic growth, often exacerbated by weak governance and inequality. Alongside these human drivers, environmental change, including climate change and variability and changes in land cover and land management, exerts impacts which are often felt most acutely in societies least able to adapt. The opportunities and challenges presented by growing and moving populations, in the context of changing water availability, threaten the sustainable, equitable and efficient use of water resources for economic development.

As demonstrated in Chapter 2, the evidence is overwhelmingly in support of anthropogenic global warming, and it is notable that climate science has unequivocally demonstrated that observed historical climate change is due to anthropogenic emission of fossil carbon (Box 1.1). In the presence of overwhelming evidence, the debate has now shifted towards understanding the regional and local consequences of warming, and their impacts on hydroclimatic variability and extremes. Revealing the regional picture adds additional uncertainty and raises the crucial question of how much additional evidence must we wait for before we act, either in mitigation of future change, or in order to adapt to what may constitute a ‘new normal’ range of climatic variability? There are

Box 1.1 The Paris Agreement

The *Accord de Paris* is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC 2015), dealing with greenhouse-gas emissions mitigation, adaptation, and finance, starting in the year 2020. The agreement was negotiated by representatives of 196 countries at the 21st Conference of the Parties of the UNFCCC in Le Bourget, France, and adopted by consensus on 12 December 2015. The Agreement’s long-term goal is to keep the increase in global average temperature to well below 2°C above pre-industrial levels, and to limit the increase to 1.5°C, to substantially reduce the risks and effects of climate change. Under the Agreement, each country must determine, plan, and regularly report on the contribution that it undertakes to mitigate global warming. No mechanism forces a country to set a specific target by a specific date, but each target should go beyond previously set targets. In addition to reporting information on mitigation, adaptation and support, the Agreement requires that the information submitted by each country undergoes international technical expert review.

The consequences of failing to meet the Paris commitments for flooding and water resources are potentially serious, although there is considerable uncertainty in current projections (see Chapter 2). Even with 1.5°C warming, significant increases in rainfall and therefore flood risk are likely, particularly in flood-prone south-east Asia. The outlook for water resources is also strongly dependent on the Paris Accord, with projections of exacerbated water scarcity in already drought-prone areas, should the 1.5°C commitment not be met. Nonetheless, much uncertainty remains, not least because the pathways to 1.5°C involve changes not only to greenhouse gas concentrations but also to atmospheric aerosols and land use.

UNFCCC. (2015). *Paris Agreement*. Available at: https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf.

many tools at our disposal to answer such questions. Indeed, the challenge to policy-makers and their advisors, and to practitioners in the field of water management, is to extract the salient information on which to base decisions from the plethora of data currently available on the subject (see Chapters 2 and 14).

Whilst global attention has quite properly focused on climate change, widespread policy-driven changes in land cover and management also rank amongst the most striking perturbations to the natural environment that impinge on the water sector. Land cover changes may occur by direct policy intervention; they may also occur as land managers respond individually to market forces and the regulatory environment. Together these changes can also impact land use (tree planting, agricultural practices) by affecting what it is economic to do in the rural environment. The impact, for example, of nitrate on long-lived groundwater quality is of particular note (Chapters 3 and 4), as is the impact of regulatory practices on water quality as evidenced by the EU Water Framework Directive, which is credited with driving a significant, but small, improvement in aquatic biodiversity (Chapter 5). Policies and economic incentives exert a powerful control over land management and agriculture, with impacts that are often felt more immediately and with greater certainty than climatic variability or change but which also act as threat multipliers or stressors of freshwater ecosystems when combined with climate change (e.g. algal blooms, Chapter 4; invasive species proliferation, Chapter 5).

Demographic drivers of change include the growth of global population centres in Asia and Africa, including 'mega-cities' with populations greater than 10 million. Nonetheless, the reality of population growth, urbanization, and the growth of agriculture to support a growing affluent population in the developing world will have profound consequences for water consumption (Chapter 8) and for water quality. As such it is vital to consider not only the physical and natural consequences but also the potential political responses in the light of projected growth of urban populations (Chapters 12 and 18).

Water plays a crucial role in many sectors of the economy and is frequently analysed as a factor of production or as a public economic good. Connections with the energy and agricultural sectors are often highlighted, not least because agriculture consumes by far the most water of any economic sector, and reliable water supplies are needed for energy production. These linkages serve both to amplify the sensitivities of the water sector to global change, and to mandate broad consideration of water-related impacts on other economic sectors in policy development and the consequent enactment of management decisions, particularly in relation to water allocation and reallocation in a rapidly changing world (Chapter 8).

The global importance of water in industrialized and developing economies is also recognized via the Sustainable Development Goals (SDGs), which explicitly mandate universal and equitable drinking water supplies and improved sanitation services, sustainable water withdrawals and protection of ecosystems (Box 1.2). Compared with the earlier Millennium Development Goals, the SDGs bring a stronger and broader framing of sustainable management of water resources to meet human and environmental needs. The role of water for development is partly to alleviate acute poverty and to protect vulnerable populations from water-related risks, especially due to extreme hydrological variability and disease associated with poor sanitation. But there is also a role for water systems to remove the time and effort burden associated with more costly, labour-intensive means of water service provision, which are borne largely by women in rural Africa and Asia, so that individuals and societies are free to devote more attention

Box 1.2 The Sustainable Development Goals

The SDGs are a collection of 17 global goals set by the United Nations General Assembly in 2015 (United Nations 2015). The goals are broad and interdependent, yet each has a separate list of targets to achieve. The SDGs cover social and economic development issues including poverty, hunger, health, education, global warming, gender equality, water, sanitation, energy, urbanization, environment and social justice. The Sustainable Development Goal No. 6 for water and sanitation has eight targets and 11 indicators that are being used to monitor progress towards the targets. Most are to be achieved by the year 2030. The first three targets relate to drinking water supply and sanitation. Worldwide, 6 out of 10 people lack safely managed sanitation services, and 3 out of 10 lack safely managed water services. Targets 4 to 6 relate to water-use efficiency, integrated water resources management and transboundary cooperation, and the protection and restoration of freshwater ecosystems, acknowledging that water-related ecosystems underpin many other SDGs. The final two targets are to do with the implementation of SDG 6; international cooperation and capacity building, and stakeholder participation, are both essential if the SDG 6 targets are to be achieved.

United Nations (2015). Transforming our world: the 2030 Agenda for Sustainable Development; Resolution adopted by the General Assembly on 25 September 2015. New York, United Nations.

United Nations (2018). Sustainable Development Goal 6, Synthesis Report 2018 on Water and Sanitation, New York, United Nations.

to other activities. Whether the SDGs lead to lasting change or whether they present an impossible-to-fulfil dream is the subject of discussion in Chapter 17.

1.3 Responses to Change: Technology, Information, Equity

Much has been done already by scientists, policy-makers and water managers to respond to the challenges set out above. Their complexity is overwhelming, and it is essential that we learn from those past experiences in order to refine our understanding of potential responses, which must draw not only on the development of new technology, but on social, political and economic innovation. As Grey highlights in Chapter 19, it is insufficient to consider water infrastructure in isolation. Investment in infrastructure can succeed only if accompanied by investment in information systems and in building strong institutions for managing the resulting systems. Moreover, as with any large investment, it is necessary to consider not just economic efficiency in the comparison of benefits and costs, but also to consider how benefits accrue amongst groups different from those who bear the social, political, and economic costs. A broader view of hydrological infrastructure is that it is ultimately for mitigating the effects of hydrological variability (Chapter 19). This view sees an increasingly important role for distributed storage, and acknowledges the links between water, energy and food, any of which can be stored or traded as a substitute for lacking a reliable supply of the other (Chapter 8).

Wastewater treatment technology has also developed rapidly over the past several decades. As noted in Chapter 16, technology capable of treating water more cheaply